AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

1791 Tullie Circle, NE Atlanta, GA 30329 404-636-8400

TC/TG/TRG MINUTES COVER SHEET

(Minutes of all meetings are to be distributed to all persons listed below within 60 days following the meeting.)

TC/TG/TRG NO. TC4.11 **DATE:** April 10, 2002

TC/TG/TRG TITLE: Smart Building Systems

DATE OF MEETING: January 16, 2002 **LOCATION:** Atlantic City

Members Present	Appt	Members Absent	Appt	Ex-Officio Members and Additional Attendance
Les Norford, Chair (V)	02-	Carlos Haiad, (V)	99-	Osman Ahmed
John House, Vice Chair, Research Subc (V)	01-03	Srinivas Katipamula (V)	00-04	Peter Armstrong
Michael Kintner-Meyer, Communications and Integration Subc (V)	99-03	Arthur Dexter, International member (V)	01-05	Jim Butler
Todd Rossi, Fault Detection Diagnostics Subc, (V)	99-03	Michael Brandemuehl, CM	99-	Peter Gruber
Natascha Castro, Secretary, Web Master (V)	01-04	Thomas Engbring, CM	96-	Keith Temple
Steve Blanc, (V)	99-03	Brian Kammers, CM	98-	Peng Xu
Barry Bridges (V)	02-	Ron Nelson, CM	99-	Don Aymann
James W. Gartner (V)	02-	Barry Reardon, CM	01-	Jon Douglas
Rich Hackner, (V)	01-05	Dave Branson, CM	01-	Tim Salsbury
John Seem, (V)	99-03	James Braun, CM	00-	Par Carling
Mike Brambly, Testing and Evaluation Subc, CM	01-	Hung Mahn Pham, CM	00-	Rodney Martin
Phil Haves, (V)	01-05	Robert Old, CM	01-05	Virgil Seribo
Agami Reddy, CM	01-	George Kelly, CM	01-	Hofu Kiu
John Mitchell , CM	00-	Carol Lomonaco, , CM Program Subc	00-	Gene Strehlow
		Charles Culp, CM	00-	Song Zhang
		David Kahn, CM	96-	David Shipley
				Kirstin Heinemeier
				Paul Reimer
				Glenn Remington
				Zach Obert
				Curtis Klaassen
				Pornsak Songkakul

(V) = voting member, Membership status as of 9/01

DISTRIBUTION:

ALL MEMBERS AND CORRESPONDING MEMBERS OF TC/TG/TRG,

TAC CHAIR: Edward Gut

TAC SECTION HEAD: Eckhard Groll

ALL COMMITTEE LIASONS AS SHOWN ON TC/TG/TRG ROSTERS:

Program: Emil E. Friberg Manager Of Technical Services: Martin J. Weiland

Research: Sheila Hayter Manager Of Research: William W. Seaton

Standards: David Knebel Manager Of Standards: Claire B. Ramspeck

Journal: Chad Dorgan

TEGA: William Knight

Special Publications: Joseph Driscoll

ADDITIONAL DISTRIBUTION: Visitors listed above

ASHRAE TC ACTIVITIES SHEET

DATE: 30 Jan 2002

TC NO. TC4.11 TC TITLE: Smart Building Systems

CHAIR: Les Norford VICE CHAIR: John House

TC Meeting Schedule

Location, past 12 mo.	Date	Location, next 12 mo.	Date
Cincinnati	6/26/01	Honolulu	6/23/02
Atlantic City	1/15/02	Chicago	1/28/03

TC Subcommittees

Subcommittee	Chair
Fault Detection and Diagnostics	T. Rossi
Utility EMCS	M. Kintner-Meyer
Testing and Evaluation	M. Brambley
Research	J. House
Program	C. Lomonaco

Research Projects

1043-RP Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers

1139-RP Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

Long Range Research Plan (as approved by TC 4.11 at the Cincinnati Annual Meeting)

Rank	Title	RTAR Written	RTAR Approved	W/S Written	TC Approved	To RAC ?
1	Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II	Yes	9/00	Yes	Yes	No

2	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Yes	No	Yes (3rd draft)	No	No
3	Method of Testing FDD Tools for AHU's (was Benchmarking of FDD Tools for AHU's)	Yes	No[1]	No	No	No
4	Smart Sensor Systems for Reducing Measurement Errors in AC Systems (was Development of Fault Detection and Diagnostics for Sensor Failures)	Yes	No	Yes (1st draft)	No	No
5	Concept of Self-Configuring Control Systems	Yes	No	No	No	No
6	Prototyping and Field Testing of Utility – Consumer Information Services	Yes	No	Yes	No	No
7	Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Yes	No	Yes	No	No

Handbook Responsibilities - none

Standards Activities - none

Technical Papers from Sponsored Research

Final report for ASHRAE Research Project RP-1011, "Utility/Energy Management and Control Systems (EMCS) Communication Protocol Requirements" is available on the TC 4.11 web site.

Results from the ASHRAE Research Project RP-1139, " Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment " have been published in the January 2001 issue of HVAC Journal.

Final report for ASHRAE Research Project RP-1043, " Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers" is available on the TC 4.11 web site.

Technical paper from 1043-RP, Comstock, M.C., Braun, J.E., and Groll, E.A., "The Sensitivity of Chiller

Performance to Common Faults," International Journal of Heating, Ventilating, Air-Conditioning and Refrigerating Research, Vol. 7, No. 3, pp. 263-279, 2001.

Technical paper from 1043-RP, Comstock, M.C., Braun, J.E., and Groll, E.A., "A Survey of Common Faults for Chillers," ASHRAE Transactions, Vol. 108, Pt. 1, 2002.

TC Sponsored Symposia (past 3 years, present, planned)

Title	**Date (Given or Planned)**
Recent Results from Fault Detection and Diagnostic Research (Norford)	Atlanta, 1/01
HVAC Diagnostics: Development to Implementation Part 1 (House)	Atlantic City, 1/02
HVAC Diagnostics: Development to Implementation Part 2 (Dexter)	Atlantic City, 1/02

TC Sponsored Seminars (past 3 years, present, planned)

Title	**Date**

	(Given or Planned)
Practical Experience Using DDC Systems for HVAC Commissioning and Continuing Evaluation (Bridges; TC1.4 lead with TC1.7, TC4.11 and TC9.9 as co-sponsors	Dallas, 2/00
Deregulation for Dummies (Haiad)	Dallas, 2/00
Evaluating the Benefits of Fault Detection and Diagnostics	Dallas, 2/00
Providing for the Most Important Part of a Smart Building Control System: People (Bridges)	Minneapolis, 6/00
Control Systems Integration, What's Happening with Practical Open-Architecture Solutions (TC 4.11 co-sponsor)	Minneapolis, 6/00
Deregulation and Energy Efficiency in the State of California (Haiad)	Minneapolis, 6/00
Diagnostics from an Operations Perspective, Needs and Experiences (Rossi)	Atlanta, 1/01
Adding New Life to Old System-Control Retrofit Case Studies (TC 1.4 lead)	Atlanta, 1/01
Maximizing Facility Performance with Computerization and Controls (Gartner)	Cincinnati, 6/01
Data Modeling for Building Operations (Kintner-Meyer)	Cincinnati, 6/01
BACnet Manufacturers Association (BMA)- New role in Testing Interoperability of BACnet Systems (Newman)	Cincinnati, 6/01
Wireless DDC Systems (TC 1.4, Bridges lead)	Cincinnati, 6/01
Intelligent Agents What They Can Do For You (Ahmed)	Honolulu
Self-Configuring Control Systems: What are the Potential Benefits? (TC 4.6 co-sponsor)	Honolulu
Experience with Demand Responsiveness Program (Kintner-Meyer)	Honolulu
Automated HVAC Functional Testing (Haves)	Honolulu/Future

TC Sponsored Forums (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
Specifying Open Lonmark DDC Systems	Atlantic City, 1/02
Addressing the Need for Data Modeling Beyond Building Design- What Role Should ASHRAE Play	Future
New Sensor Technology, Other New Technologies (Kintner-Meyer)	Future
Should ASHRAE be involved in IFC and XML (Brambley)	Future

TC Sponsored Public Sessions (past 3 years, present, planned): None

Journal Publications (past 3 years, present, planned): None

Minutes summary and activities sheet submitted by: Natascha Castro, TC 4.11 Secretary

Atlantic City: Tuesday, January 16, 2002

Call to Order, Roll Call, Introductions

The meeting was called to order at 3:30 PM with Chairman Les Norford presiding. A roll call showed that a quorum was present. In attendance at the meeting were Norford, House, Kintner-Meyer, Rossi, Castro, Blanc, Bridges, Gartner, Hackner, Seem, Haves. Eleven of 13 voting members were present. *There was confusion about Phil Haves' voting status. The roster indicated Phil was not a voting member, however, Chairman Norford confirmed that Phil is a voting member.*

Norford distributed the minutes from the Cincinnati meeting, the Agenda, and the revised scope and organization of the committee (the call-to-meeting letter and the agenda are in Appendix A). He then asked for introductions. The approval of minutes were held until after the report from the Research Liason.

Report from the Research Liason.

Sheila Hayter reminded the TC that we have two prioritized RTARs. Workstatements are due to ASHRAE by May 15, 2002 and RTARs are due Sept. 1, 2002. Sheila recommends RTARs be given to her for comment prior to sending them to ASHRAE.

One RTAR on "field performance assessment" is on the 2002 ASHRAE Research plan. Sheila encouraged submitting a work statement.

Approval of Minutes

The minutes of the last meeting were reviewed. Norford requested comments for minutes submitted from Atlanta meeting. Minor corrections were made to the member list.

Motion 1: Motion to accept minutes from the June 2001 meeting (Motion: House, 2nd: Blanc)

Vote: For: 10 (CNV)

Against: 0

Abstain: 0

Motion passed

Announcements (Norford):

- The research budget has been shrinking. At this meeting, only 2 of 6 proposals were approved while 25 are on hold.
- At the TC chairs meeting the recommendation was made that handbook reviewers follow the guidelines established for them. There was a request for materials for the Insights publication. In addition, the ASHRAE website is making space for TC's to transfer their individual websites. There will likely be a meeting for webmasters at the summer meeting.

Norford then asked for updates from the subcommittee chairs.

Technology Development Subcommittee (Rossi)

Rossi reported that there were two projects in this subcommittee, 1139-RP and 1043-RP.

Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment (1139-RP).

Rossi reported that the 1139-RP is completed. The principle investigator, Agami Reddy then made a 10 minute presentation summarizing the findings. Reddy reported that results have been published in the January 2001 issue of HVAC Journal and that all data from the chiller and Matlab routines are available on a cd.

Project is to review four model types plus two on-line training techniques. Reddy summarized some key findings which included that:

Models by Gorden and Nang were relatively less accurate approx 3-5%, others better than 3%.

Adaptive model training can provide better FD capability,

MLP model and GN models most suitable

FD based on model predictions is suitable

Sliding windows under ORLS with 100-200 points are appropriate

GN model can be started with 20-30 points

<u>Motion 2</u>: Motion to accept the final report for 1139-RP (Motion: Rossi, 2nd: Norford)

It was requested that the final report be posted on website with the appropriate disclaimer and copyright.

Vote: For: 11

Against: 0

Abstain: 0

Motion passed

Rossi Reported that the subcommittee had discussed new research plan. Three areas were put on research plan: component FDD, sensor fault detection, and self-configuring control systems. It was agreed that we want to maintain a focus on new technology development associated with the FDD area and future work statements would be in that area.

Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers (1043-RP) Phase 1.

House reporting for Seem. Met with contractors Monday and went over the dynamic model for modelling chillers which had good results and tracked well. Several reports were submitted which included: 1)literature review, 2)experiments, 3)database with normal& fault data, and 4)sensitivity with steady state modeling. They are currently working on a matlab simulation program. In addition, work to be done includes reviewing the reports and responding to committee recommendations.

<u>Motion 3</u>: Motion to accept the final report for 1043RP subject to editorial changes suggested by the PMS (Motion: House, 2nd: Hackner)

There was some discussion regarding the format of the Matlab program- write in C++ linked to Matlab for the interface. It was requested that the software be provided as a stand-alone software.

Vote: For: 10 (CNV)

Against: 0

Abstain: 0

Motion passed

Norford asked for a recap of phases I and II.

Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II. Rossi stated that this work statement has been ready and waiting to go. Haves recommended that the work statement be revisited and checked and that quantitative benefits to ASHRAE and the society be added if appropriate. It was recommended that the Author and PMS chair review the work statement and then submit it to Sheila Hayter for her suggestions. The deadline being May 15 so that RAC can act on it in June.

Self Configuring Control Systems- the subcommittee reviewed an RTAR "Design of a Self-Configuration Concepts for HVAC Control Systems". Kintner –Meyer reported that ASHRAE was concerned that perhaps industry should be doing this work. He stated that Industry was asked whether they have these products and the response was no. The subcommittee is looking to address the, "needs, technologies and potential benefits"

Kintner –Meyer requested volunteers to help with the work statement. TC 1.5 discussed interest and Pornsak volunteered to be the liason to 1.5. Haves stated individual companies may also be concerned about disclosing their research work, while the TC can advance a more general push for the technology. Osman agreed to review the work statement.

Smart Sensors- No new progress in this area, but Dexter is going to prepare something for the next meeting.

Rossi also reported that the two FDD symposiums at this meeting were well attended.

The minutes of the subcommittee meeting are in Appendix C.

<u>Communications and Integration Subcommittee (Kintner-Meyer)</u>

Kintner-Meyer reported that there is a work statement being developed on Prototyping and Field Testing of Utility – Consumer Information Services is a continuation of RP-1011. It consists of two phases, Phase 1 is to be carried out in a simulated environment, while Phase 2 would be deployment and would also entail a mapping of the data objects to BACnet, requiring a change to the BACnet standard. This work statement had not yet been approved. It was stated that we should get buy-in from BACnet group. At this point the work statement is until put on hold. The BACnet committee is interested but are working on standard BACnet work. KM recommends to keep communication open with the group and facilitate discussions as possible.

No program this meeting.

The minutes of the subcommittee meeting are in Appendix D.

Testing and Evaluation Subcommittee (Brambley)

The subcommittee discussed two work statements,

Method of Test for Air-Handling Unit Fault Detection and Diagnostic Tools. House is the lead author and presented a summary of the work statement. It is a follow on to 1025RP where tw3o fault detection methods were tested in a real building. Out of that work, a test plan was developed for evaluating FDD tools. The intent was to take this further to establish a complete method of test. The scope involves developing labeled data sets, performance metrics for evaluations, and test plan that would integrate those two aspects in a more rigorous or comprehensive manner to evaluate methods. It is intended to get the operator out of the loop and intended for developers(controls manufacturers/researchers) as a development tool. House requested reviewers in addition to those who volunteered last time (Phil, West, Price, Young). New volunteers were Brambley, Norford, Xu, and Rossi. The RTAR for this has been approved.

Field Performance Assessment of Package Equipment to Quantify the Benefits for Proper Service and Assessing the Long-term Need for Monitoring, FDD, and Continuous Commissioning Technology The RTAR for this has been approved, it is on the ASHRAE priority list. Rossi distributed and presented the work statement with changes since Cincinnati.

Rossi reported that the subcommittee had discussed a cover letter to include potential bidders to stress the bid-ability of this project. Rossi pointed out changes in this version. Following the puch to quantify potential benefits, additional information was included to show a ballpark analysis of the energy impact. KM suggested quantifying the capacity reductions that could be achieved using these changes, highlighting the potential for savings.

There was some discussion regarding the reasons for selecting the size of the units to be tested. Osman recommended that ARI be contacted to input a good range for the size.

In this work statement the number of units tested was reduced from 500 to 375 from the last round of comments. An analysis is included to determine the number of units required to generate statistically significant results which shows that 150 units should be tested. The work statement shows that 375 units should be tested, to ensure the necessary responses. Brambly recommended that this information be moved to a footnote, or cover letter. Blanc suggested reducing the number to 300 and leaving the number of units to be fixed at 75. It was agreed that this ould be adequate to collect the necessary data and would also be more cost effective. The cost is thereby reduced to 120K.

Motion 4: Motion to approve the work statement, Field Performance Assessment of Package Equipment to Quantify the Benefits for Proper Service and Assessing the Long-term Need for Monitoring, FDD, and Continuous Commissioning Technology, as discussed and amended (Motion: Rossi, 2nd: Bridges)

Vote: For: 10 (CNV)

Against: 0

Abstain: 0

Motion passed

Volunteers were solicited for the PES (Brambly, Blanc, Rossi, House)

No program this meeting or for Honolulu.

The minutes of the subcommittee meeting are in Appendix E.

Research Subcommittee (House)

House reported that the subcommittee met for 45 minutes on Sunday, during which, Haves led a brainstorming session to identify the characteristics of smart buildings of the future. In the course of the session, it was noted that there was considerable overlap with TC's 1.4, 4.6, and 9.9. It was recommended that liaisons be selected to encourage and seek out active collaboration for research. Bridges, Young, Gartner volunteered as liasons to 1.4. Gartner volunteered as a liason for 1.7. It was suggested that Kristin Heinemeier be asked to liase with 9.9. Haves, Brandemuhle, Braun, and Kintner-Meyer volunteered as liasons for 4.6. For lifecycle there are also some links to 1.5. Sangakul, and Branson volunteered as liasons to 1.5. Sangakul suggested posting the liasons so that as workstatements are generated, champions are identified to advance the work.

House to distribute minutes from research to the TC following the meeting.

Haves discussed the need for being proactive in liasing with other tc's to use areas of overlap to the benefit of research and also for handbook, noting that the chapter divisions among TC's may not be the most effective arrangement for collecting material.

Norford Reported that in Honolulu there will be a meeting of section 4 Research subcommittee Chairs, TC Chairs, RAC, and TAC. To share ideas on topics of interest, to coordinate handbook efforts.

The long range research plan must be reprioritized at the summer meeting.

Program Subcommittee (House reporting for Lomonaco)

1) Seminar Osmad on "Intelligent Agents- What they can do for you"- ready to go for Honolulu. It is a new technology in the computer field. Using software agents to collaboratively use and share information that can be used to provide useful information. The seminar is designed to present a description of what it is , a software implementation, a demonstration, and hopefully a fourth paper on intelligent agents for security.

2)Brambly is chairing a seminar on "Self-Configuring Control Systems: Needs, Technologies, Potential Benefits." Speakers are covering concepts to what is going on with computer networking. TC 1.5 voted to cosponsor.

3) Haves has a seminar on Automated Functional Testing with 4 speakers for Honolulu or Chicago.

Other ideas:

4) Kintner-Meyer seminar on Wireless (Chicago)

5) Proposed seminar for chicago: (rossi) FDD from an operators perspective.

6) Forum on data-modeling

Motion 5: Motion to co-sponsor of the 4.6 seminar on "Experiences on Demand Responsiveness" (Motion: House, 2nd: Kintner-Meyer)

Vote: For: 10 (CNV)

Against: 0

Abstain: 0

Motion passed

Motion 6: Motion to accept the prioritized list and co-sponsorship for the Honolulu program as presented by House (Motion: Blanc, 2nd: Rossi)

1. **Osmad Seminar "**Intelligent Agents- What they can do for you"
2. **Brambly Seminar "**Self-Configuring Control Systems: Needs, Technologies, Potential Benefits"
3. **Haves Seminar "**Automated Functional Testing"

Vote: For: 10 (CNV)

Against: 0

Abstain: 0

Motion passed

Programs as subsequently approved by ASHRAE are tabulated at the beginning of these minutes.

Gartner announced that there is a Forum on Mold, Fungi, & other spores that may be of interest to the committee.

Packages due 2/8 for Honolulu and 8/2 for Chicago.

Handbook

No handbook report.

Web-site

The link is through the ASHRAE website. Minutes will be posted as well as seminar slides. Seminar chairs have been requested to submit slides.

Old Business

No old business

New business

Add technical papers to the list in minutes.

Les requested names of people interested in becoming members. Submit requests to Natascha Castro.

Adjournment

At 6 p.m.

Motion 8: Motion to adjourn (Motion: Hackner**, 2nd:** Gartner **)**

Vote: Unanimous

Motion Passed

Appendices

A. Call to Meeting and Agenda
B. Scope and Organization
C. Technology Development Subcommittee Report
D. Communications and Integration Subcommittee Report
E. Testing and Evaluation Subcommittee Report
F. TC4.11 Research Subcommittee meeting/Planning Session
G. Research Plan and Activities
H. List of Subcommittee Attendees

Appendix A.

Call to Meeting and Agenda

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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1791 Tullie Circle, NE, Atlanta, Georgia 30329-2305 404-636-8400 | Fax 404-321-5478

Reply to: Les Norford

Room 5-418

MIT

77 Mass. Ave.

Cambridge, MA 02139

January 7, 2002

Dear TC 4.11 Member, International Member, or Corresponding Member:

The **TC** on Smart Building Systems and its subcommittees will meet in Atlantic City according to the following schedule:

TC 4.11 Tech. Development Sunday (1/13) 3:00-3:45p ACCC/415

TC 4.11 Comm. & Integration Sunday (1/13) 3:45-4:30p ACCC/415

TC 4.11 Testing & Evaluation Sunday (1/13) 4:30-5:15p ACCC/415

TC 4.11 Research Sunday (1/13) 5:15-6:00p ACCC/415

TC 4.11 Smart Building Systems Tuesday (1/15**) 3:30-6:00p ACCC/318**

TC 4.11 PMS 1043 RP Monday (1/14) 11:00a-12:00p Caesar/Neptune 3

The TC is the co-sponsor, with TC 1.4, of the following sessions in Atlantic City:

Symposium AC-02-12: **HVAC Diagnostics: Development to Implementation – Part 1**,

Tuesday, 1/15/2002, 8:00 AM - 10:00 AM, ACCC/418, Chair: John House

Symposium AC-02-12: **HVAC Diagnostics: Development to Implementation – Part 2**,

Tuesday, 1/15/2002, 10:15 AM – 12:15 PM, ACCC/418, Chair: Arthur Dexter

See the ASHRAE Program Booklet to confirm session locations and times.

Attached is a draft agenda for the full TC 4.11 committee meeting in Atlantic City. I hope to see you all there.

Les Norford

Chairman, TC 4.11

ASHRAE TC 4.11, Smart Building Systems

2001 Annual Meeting, Atlantic City

AGENDA

Location: Room 318, Atlantic City Convention Center

Date: Tuesday, January 15, 2001

Time: 3:30 - 6:00 p.m.

1. Roll call and introductions

2. Approval of Minutes from Cincinnati

3. Announcements
4. Research Planning (John House)
   - research roadmap
   - communicating TC 4.11 visions, goals, and priorities to ASHRAE

5. Technology Development Subcommittee Report (Todd Rossi)
   - 1043-RP, Fault Detection and Diagnostic (FDD) Requirements and Evaluation Tools for Chillers (John Seem)
   - 1139-RP, Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment (summary report from Agami Reddy)
   - Summary of Draft Work Statements
   - Other activities

6. Communications and Integration Subcommittee Report (Michael Kintner-Meyer)
   - Summary of Draft Work Statements
   - Other activities

7. Testing and Evaluation Subcommittee Report (Michael Brambley)
   - Summary of Draft Work Statements
   - Other activities

9. Program Subcommittee Report (Carol Lomonaco)
   - Feedback from symposia in Atlantic City
   - Plans for Honolulu (6/22-26/2002) and Chicago (1/25-29/2003)

10. Handbook (Les Norford)

11. TC 4.11 Website (Natascha Castro)

12. Old business

13. New business
14. Adjournment

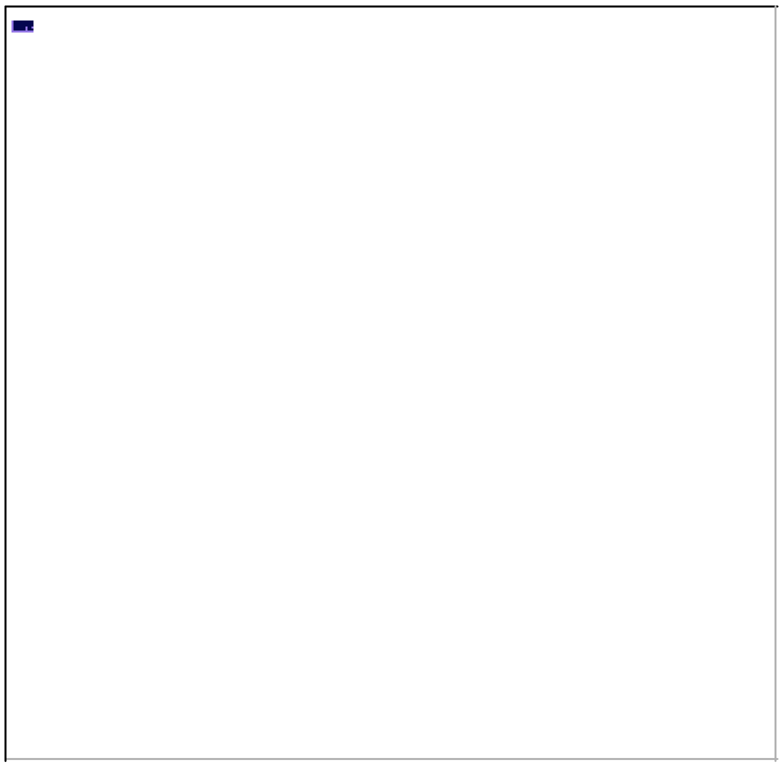
Appendix B.

TC 4.11, Smart Building Systems Scope and Organization

Revised July 1, 2001

Overall Committee Scope

The Technical Committee on Smart Building Systems (SBS), TC 4.11, is concerned with the development and evaluation of technologies that could enable the widespread application of smart building systems. "Smart" buildings should take advantage of automation, communications, and data analysis technologies in order to operate in the most cost-effective manner. This implies integration of building services such as HVAC, fire, security, and transportation; the automation of many of the operation and maintenance functions traditionally performed by humans; and the interaction with outside service providers such as utilities, energy providers, and aggregators. Currently, three subcommittees form the backbone of the TC's activities: technology development, communications and integration, and testing and evaluation. The scope and activities of these subcommittees loosely follow the product development process as depicted in following flow chart and as defined in the following sections.



Technology Development Subcommittee

Scope

The Technology Development Subcommittee is concerned with research issues associated with the development of emerging smart building technologies such as (but not restricted to) automated commissioning, performance monitoring, fault detection and diagnosis, optimal maintenance scheduling, and self-configuring control. The primary outcome of research endorsed by this subcommittee is expected to be data and models that enable development of the technologies and comprehensive methods that are the basis of the technologies. An integral part of the development process is simulation and laboratory testing. Proposed designs must be tested and modified prior to field evaluation or integration with other smart building components.

Vision

The ever-increasing speed of organizational changes of the occupants in today's buildings demand greater flexibility of the building structure and the building automation system to respond to these changes. Furthermore, smart building systems offer the promise of dramatically improved building performance (e.g. comfort, reliability, and energy efficiency) and lower operating cost.

HVAC equipment automated commissioning, performance monitoring, fault detection and diagnostic, and optimal service scheduling technology directs service personnel to fix equipment problems causing poor comfort, reliability, and/or energy efficiency during different stages in building life cycles. Compared to the tools available today, these technologies are more sensitive to significant performance degradations, they are more aware of the entire building performance picture, and they help accomplish service tasks quicker.

Plug-and-play or self-configuring control systems are critical technologies needed to make buildings more flexible and to reduce the labor and expertise needed to install and maintain building automation systems. Self-configuring controllers understand their role in the building system. They are aware of the presence of other devices in the building and how they relate and interrelate with them to collectively provide building services. This high level of functionality is provided by highly skilled people at great cost today. When these people are freed for these tasks and costs are reduced, sophisticated building automation systems will become even more wide spread and the people will move on to even higher level tasks leading toward finely tuned and optimally performing buildings.

Research Agenda

To accomplish these broad goals, the subcommittee is focussing its near-term effort in the following directions:

1. Fault detection and diagnostic (FDD) technology focused on HVAC components like refrigeration cycles (including chillers, direct expansion cooling, and refrigeration) and air handing units.
2. Technologies supporting equipment FDD including smart sensor systems.
3. Self-configuring control systems

Research Projects

The sections below list ongoing (o) and planned (p) research related to the subcommittee's technology development goals. The subcommittee has no completed (c) or rejected (r) research projects. The studies are also shown on a timeline provided as a separate document.

o 1043-RP Fault Detection & Diagnostic Requirements & Evaluation Tools for Chillers – Purdue University was provided a no cost extension until the expected completion date on 6/31/01.

o 1139-RP Development and Comparison of On-line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment – Drexel University was provided a no cost extension until the expected completion date on 8/31/01.

p Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II - Approved in Minneapolis and will submit to RAC AFTER Phase I (1043-RP) is completed. RTAR approved 9/00.

p Smart Sensor Systems for Reducing Measurement Errors in AC Systems - One page description exists. A two page version is being discussed and revised.

p Self-configuring Control Systems – RTAR+ document under development for Cincinnati.

There are three phases associated with this the chiller fault detection project. The first phase is an ongoing project (1043-RP) where the important faults are being considered and the appropriate sensors will be identified. In addition, a model for simulating chiller behavior is being developed that can be used to evaluate FDD performance for the different faults. The second phase is a planned research project where the FDD methods will be developed, implemented, and evaluated through simulation. This phase will produce a comparison of alternative FDD methods and recommendations for real-time implementation. Finally, the third phase will involve the real-time implementation and evaluation of FDD methods within the laboratory and the field. It is hoped that by the end of the third phase, an algorithm will be specified for incorporation within commercial products.

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Communications and Integration Subcommittee

Objective

The Communications and Integration Subcommittee is concerned with research issues associated with enabling the seamless interaction of smart building components and services within buildings, among buildings, or with an outside third party. An important aspect of this work is to identify the information that is necessary to support smart building technologies, and to identify the requirements of communication protocols to support the exchange of this information between different building services, between buildings and utilities, between multiple buildings, with outside service providers, etc. Another aspect of this work deals with the technical issues, challenges, and opportunities of integrating building systems to utilize synergies among the system components to achieve high performance building operation and highly productive work and living environments.

Addressing the Need for Innovative Building Automation Communications Systems and Services

Key to the high-performance operation and maintenance of a smart building system is the communication among various building system components that enables innovative control, monitoring and diagnostics concepts. The ever-increasing speed of organizational changes of the occupants in today's buildings demand greater flexibility of the building structure and the building automation system to respond to these changes. This will require highly flexible building automation system and a communication infrastructure to support the flexibility demanded.

Wireless sensors and control systems are emerging for building automation applications that provide a great opportunity to support and expand innovative and flexible control concepts to allow personalized and localized buildings control. As personalized and localized controls become reality, the number of sensors and control points in a building will grow significantly. This increase in sensor and control points will require a communication infrastructure that can re-configure itself to quickly establish connectivity to the added devices to the entire network. Plug-and-Play concepts are necessary for the rapid deployment of new sensors and control equipment with minimal or no set-up time.

The convergence of data and building automation networks will enable innovative remote building monitoring and control services. The need to reduce cost for the building operation will drive innovation for building remote monitoring, diagnostic, and control concepts. New building cooling, heating, and power technology and distributed power concepts will enable buildings to become zero-buyers of electricity or even net producers of electric power, whenever there is an economic incentive. To evaluate the economics of the trade-off between on-site electricity production and buying electric power from the service provider requires instant communications to the electricity markets to receive the hourly or sub-hourly changing price information. With these new technologies in place, the defining lines between the supply and demand sectors become increasingly blurred. Advanced load management strategies will seek optimal operation and dispatching of heating, cooling, and power system not only within the framework of a single building but also in a campus setting including many buildings. To engage in these new services, constant interactions among the energy consuming and producing must be in place. This will require information protocols and standards to support these services over wide-area networks.

Addressing the Need for Integration of Building Systems

The subcommittee addresses integration issues at three levels:

1. Integration of existing building automation functions (e.g., HVAC, lighting, fire alarm, safety and security systems)
2. Integration of advanced automated fault detection and diagnostic methods and tools into existing HVAC control systems
3. Integration of different automated fault detection and diagnostic tools to enhance each other’s functionality and effectiveness.

<u>Integration of existing building automation functions:</u> Building control system in the past have been developed and deployed independently from each other to address a specific building need. HVAC, lighting, fire alarm, and safety systems emerged in their specific industries with a set of standards and safety requirements. To fully utilize cost savings opportunities the building control systems will need to be integrated into one building automation system. Integration will support not only the use of common communication infrastructure but also seek synergetic interactions that provide enhanced functionality and value added.

<u>Integration of advanced automated fault detection and diagnostic tools into existing HVAC controls:</u> With the transition of automated fault detection and diagnostics tools from the research to the demonstration and deployment stage, the new tools need to be integrated into existing HVAC equipment control or building automation systems to share sensor and equipment information for the diagnosis.

<u>Integration of different advanced fault detection and diagnostics tools into larger diagnostics systems.</u> As more fault detection and diagnostics tools for HVAC equipment are being developed, it becomes increasingly important to harmonize the results of each diagnostic component in order to resolve discrepancies in the diagnosis and to seek internal corroboration and mutual substantiation of the same underlying problem. As the complexity of the HVAC fault detection and diagnostic system grows, it will be essential to maintain internal consistency among different diagnostic tools.

<u>Near-Term Research Agenda of the Subcommittee:</u>

To satisfy the science and technology needs mentioned above, the subcommittee will work on the following research topics:

1. Establish communication protocols that support automated data exchanges between service providers and buildings automation system to enhance energy efficiency, high performance of equipment operations and cost savings in buildings.
2. Promote plug-and-play and self-configuration concepts to avoid set-up problems of HVAC control systems.
3. Research the use of wireless sensors and controls for building operations and the integration into existing wired controls infrastructures.
4. Research integration opportunities to enhance the value of each single controls and diagnostics component.

The section below lists ongoing (o), planned (p), completed (c) and rejected (r) research related to the topics above.

(c) 1011-RP Utility/EMCS Communication Protocol Requirements – completed in summer 1999. The primary objectives of research project 1011-RP were: 1) to identify potential new information services that utilities or electricity suppliers are likely to offer to their customers, 2) to determine the communication and data requirements to establish these services, and 3) to develop data object models that support interoperability for the implementation of the services.

(p) Prototyping and Field Testing of ASHRAE’s Utility Consumer Interface Models (UCIM) – A work statement has been written. This research is an extension of the completed 1011-RP project. ASHRAE proposes a project for prototyping and testing a set of selected information services defined in research project 1011-RP. The project focuses on the prototyping and testing of information services under lab conditions in which the communicating parties are simulated. Co-sponsorship by SSPC 135 is sought.

(p) Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic (FDD) Systems – A work statement has been developed. The proposed research will identify conditions in which two or more fault detection and diagnostic systems of may find disagreeing conclusions for the same underlying system faults. The research will identify solutions for resolving the discrepancies in the diagnostics provided by multiple fault detection and diagnostic systems.

(p) Self-Configuration of HVAC Control Networks – RTAR is being developed. The proposed research will describe novel self-configuration concepts used in data networking and personal computer technologies and analyze their applicability to HVAC control networks. Self-configuration methods in personal computer technologies have been proven to significantly reduce the set-up time and set-up errors. It is expected that similar advantages can be realized for when installing complex HVAC control networks in large buildings.

Testing and Evaluation Subcommittee

Objective

The Testing and Evaluation Subcommittee is concerned with research issues associated with assessing the benefits (market potential) and performance of smart building technologies such as fault detection and diagnostics, automated commissioning, self-configuring systems, etc. Research endorsed by this subcommittee is expected to result in data, metrics, methods, and tools/standards/guidelines for quantifying smart building system benefits and performance in a standardized manner, as well as findings from the actual application of these metrics, methods and tools. The sections below describe the goals of the subcommittee in more detail and list ongoing (o), planned (p), completed (c) and rejected (r) research related to these goals.

Assessing the Benefits of Smart Building Technologies

Research related to assessing the benefits of smart building technology can help define and justify research on such technology by establishing how (and by how much) the performance of existing technology can be improved. Successful studies of this nature can lay the groundwork for acceptance of new technology by end-users. To be successful and to gain support from ASHRAE, studies should be targeted at existing technology that is known to have performance problems. Furthermore, proposed studies should have a clear procedure and set of metrics (or at least such procedures and metrics should be perceivable at the start of the research) that will enable performance to be quantified in an objective manner (e.g., energy savings, time savings, etc.). In some cases a study may include demonstrations of prototype tools that can improve performance, while in other cases the study may be limited to measuring the performance of an existing technology, as new technology does not yet exist.

The status of studies related to assessing the benefits of smart building technology is summarized below. The studies are also shown on a timeline provided as a separate document.

- **Integrated Control of Building Services**
  – RTAR was rejected by RAC and dropped from consideration by TC 4.11

- **Field Performance Assessment of Packaged Equipment to Quantify the Need for Monitoring, FDD and Continuous Commissioning**
  – RTAR was rejected by RAC in the Fall of 2000 – a new version of the work statement is under development

Note that the second study cited above deals with field performance assessments of HVAC equipment. The outcome of this study should help establish the need for automated FDD and continuous commissioning. Studies aimed at field performance assessments of other equipment (e.g., chillers, fan coil units) may also be merited. At present, no research aimed at assessing the benefits of smart building technology have been identified for the focus areas of interconnectivity/interoperability and self-configuring systems. A proposed study in the area of integrated controls, services and facilities was rejected by RAC.

Assessing the Performance of Smart Building Technologies

Research related to assessing the performance of smart building technology is intended to produce data sets, metrics, protocols, etc. for quantifying performance, and/or to demonstrate and test specific smart building technology in pre-commercial stages of development. Successful studies will lead to tools that can be used to test the performance of smart building technology throughout its development cycle. Demonstration studies will help establish the potential of smart building technology while also identifying possible deficiencies in the demonstrated technology.

The status of studies related to assessing the performance of smart building technology is summarized below and on the timeline of the accompanying document.

- **Demonstration of FDD Methods in a Real Building (1020-RP)**
  – completed 2/00

- **Prototyping and Field Testing of Utility – Consumer Information Services**
  – championed by TC 4.11 Communication and Integration Subcommittee

- **Method of Testing FDD Tools for AHU's**
  – existing work statement needs revision

- **Evaluation and Assessment of FDD for Centrifugal Chillers – Phase III**
  – Phase II of this work is being championed by TC4.11 Technology Development Subcommittee and has not been initiated yet.

Note that the second study listed above is being championed by the Communication and Integration Subcommittee of TC 4.11; however, the testing work is closely related to the goals of this subcommittee. At present, no research aimed at assessing the performance of smart building technology have been identified for the focus areas of integrated controls, services, and facilities and self-configuring systems.

Appendix C.

TC4.11 Technology Development Subcommittee Meeting

Minutes

Atlantic City, January 14, 2002 3:00-4:00 p.m.

Notes by: John House

Todd Rossi opened the meeting by discussing 4.11 main committee priorities and Technology Development Subcommittee priorities. The three top priorities of the subcommittee are:

- FDD
- Self Configuring Control Systems
- Smart Sensors (no progress on this topic, but there is still interest and will be pursued in the next six months)

Other ideas for research:

- Dessign stage technologies
- Self-tuning simulations
- System level FDD

Michael Kintner-Meyer discussed an RTAR titled "Design of a Self-Configuration Concepts for HVAC Control Systems". The objectives are to develop requirements for self-configuring systems, design the concept, and advise ASHRAE on what role it should take in advancing the concept. The discussion last time centered on whether this was in the purview of ASHRAE. At this point it is still unclear how the topic will be received. Comments regarding the RTAR follows:

Todd Rossi – Microsoft went forward and created a defacto standard. With numerous smaller companies, it makes more sense for a standards organization like ASHRAE to step in to advance the technology.

Mike Brambley – Development of the methods is needed first, and standardization would follow. Unless the research is product specific, there’s a role for ASHRAE to develop the capabilities and then to pursue standardization.

Michael Kintner-Meyer – Literature search should see what’s out there in other fields.

Jim Braun – Go beyond conceptual design, and test an implementation through simulation.

Phil Haves – The attitude of RAC is one that does not embrace research for the sake of educating the technical committee. The TC supposedly has the expertise to advise ASHRAE.

Arthur Dexter – Is this dealing with hardware only, or with control strategies as well?

Mike Brambley – Any standards developed should accommodate both. Not in favor of simulation testing, because it would only be one particular scheme. Instead, we should try to better understand what has been done in other industries. This information is needed, even though ASHRAE might not support the effort to get this information.

Pornsak Songkakul – Indicated support for Mike Brambley’s position that we need to look at other industries.

Jim Braun – The reason a simple demonstration would be beneficial is that we would gain better understanding of the scope and nature of the challenge.

Michael Kintner-Meyer – We need liaison’s to TC 1.4 and the BACnet committees to get them involved. Barry Bridges might be a good candidate for TC 1.4. Pornsak Songakul will talk to TC 1.5. Michael Kintner-Meyer will talk to BACnet.

Mike Brambley – Could we ask TC 1.4 to tell us about what self-configurating systems they know about?

Dave Underwood – TC 1.4 research will consider it at their meeting Monday, Jan. 14, 2002.

Phil Haves – Agree with Mike Brambley’s approach of going directly to the committee.

Program Ideas:

Current meeting: FDD Symposia

Seminar Idea: "Self-configuring controls: benefits, promises and needs" (4 speakers; Mike Brambley is chair … should be ready for Honolulu)

Seminar Idea: "Automated functional testing" (Phil Haves volunteered to be chair)

Seminar Idea: "Wireless monitoring and controls" (PNNL could provide one speaker, and they have ideas for other speakers including facility managers and technology providers; Cliff Federspiel could possibly speak)

Seminar Idea: "Demand response programs" (TC 4.6 lead, 4.11 co-sponsor)

Appendix D.

TC4.11 Communications and Integration Subcommittee Meeting

Minutes

Atlantic City, January 14, 2002 3:00-4:00 p.m.

Notes by: Peter Armstrong edited by Michael Kintner-Meyer

1. Michael Kintner-Meyer reported on provided an update on work statement involving an extension to BACnet to communicate utility information (Title: *Prototyping and Testing of Utility/Customer Information Services)*. Marty Burns and Michael Kintner-Meyer submitted proposals for 1 change and 1 addendum of the BACnet standard. The acceptance of the proposals for modifications to the BACnet standard is viewed as a necessary step toward moving the workstatement forward. The work statement discusses the following 2 phases:

   Phase I: simulation of RTP (+ 8 other utility interface services) & associated proposed objects completed 2 years ago.

   Phase II: 5 sites demo (wk stmt "in pipeline" pending SP150 acceptance of Burns-MKM proposed services

   (Jim Butler (Symmetrix), BACnet committee reported the status of the BACnet committee reviewing our submittal. The SPCC 135 Utility integration working group (chaired by Keith Corbett) considering 90 proposals. In March 2002, the BACnet meeting may address if not on Monday during the Atlantic City meeting. Further scheduling issues for review of our proposal should be discussed with Steve Bushby.

   Michael Kintner-Meyer mentioned that some utilities have explored (tested) recently utility-customer communications. Steve Blanc is concerned that the utility are moving very slowly deploying new technologies due to the other more urgent business needs

2. Michael Kintner-Meyer discussed a new work statement idea that address self-configuration concepts for HVAC networks. Marty Burns points out that SP150 is exploring alternative design approaches addressing features of self-configuring concepts.; Jim Butler confirms; Les Norford supports continued to push forward.
3. Mike Brambley proposes ad hoc committee to draft RTAR before June mtg.: something rerlating to wireless comms for sensors and controls. Marty Burns volunteers.
4. Bob Old's ("oldbob") Yahoo discussion group: not much going on.

Appendix E.

TC4.11 Testing and Evaluation Subcommittee Meeting

Minutes

Atlantic City, NJ January 13, 2002

Discussion on RTAR: Topic: Field Performance Assessment of Packaged Equipment to Quantify the Benefits of proper Commissioning

Dave Shipley provided a tool to determine the population necessary to be statistically significant. Field Diagnostic Services provided the necessary data for using the tools.

25K co-funding from DOE. John Andrews, BNL, would be the program manager for DOE..

Mike Brambley asked about the statistical analysis. Question: are we determining aggregated benefits? Are we determining average savings for the entire population of faults? Or are we disaggregating into individual faults? If so, then we most likely need a larger sample. Mike asked that the statistical analysis be redone to determine the sample size necessary to obtain statistically significant results for individual faults and problems.

Todd Rossi: The work statement for this research has been discussed over the last 3 meetings.

Mike: what are the action items for this work statement?

Todd: up for voting at the TC meeting.

Phil Haves: The Work statement could be strengthened by quantifying clearly the potential benefits of this research in order to meet the ASHRAE justification criterion. You need savings numbers in BTU and dollars.

John House: TC 9.9 will be co-sponsoring the research work statement.

Phil clarified that the work statement should identify potential bidders.

Todd summarized the research and action items for this research. This work statement will be voted on. New at this meeting is the addition of 25 K co-funding from DOE and the statistical analysis.

Method of Test for Air-handling Unit Fault Detection and Diagnostics Tools

John House presented the RTAR.

This project continues the previous research in ASHRAE 1020-RP. A method of testing is necessary for new tools. It would provide the manufacturers testing procedures for their products. John listed prior art. We need labeled data sets. Data sets can be real or simulated. They need to be labeled appropriately.

What is needed?

- Labeling of data sets
- Description of standard testing methods

Phil Haves: Does it include manual and automated test procedures?

Mike Brambley: What are we testing? The method, the tools, the tools or the human ability to use the tools?

John House: Initially it was intended to have one tester to test all of the methods. He acknowledged the issue with the human interface.

Mike: There is another issue dealing with the depths of the diagnosis.

Phil suggested looking at the testing procedures that SPC140 developed for testing building simulations. There may be some parallels we could use.

Mike: ASTM has developed many testing procedures, which would provide some value for the Work statement.

John: Action items:

- Email dialog could provide comments.
- John will be emailing the RTAR out with a deadline for providing comments
- Version for the next meeting will be more refined.
- It will be mailed out prior to the next meeting.

Agami Reddy: There may be other concerns as identified in Project 1043, such as signal to noise ratio and others.

Mike Brambley: we need to define more tightly the scope of the RTAR.

New research ideas

Agami: There is a gap in how to define human comfort in the context of a smart building.

Les Norford mentioned that there was a related topic in a Forum at this meeting.

Program:

Les mentioned a potential paper on project 1039.

Mike encouraged anyone who would like to participate to think about new programs.

Minutes prepared by Michael Kintner-Meyer and submitted by Mike Brambley.

Appendix F.

TC4.11 Research Subcommittee meeting/Planning Session

Minutes

Atlantic City, NJ January 13, 2002

Phil H. leads a discussion on brain storming the big picture.

Steps:

1. Characteristics of the smart building
2. Prioritization
3. ???

Characteristics of Smart Buildings for the future (brain storming)

1. Self configuring control systems (Brambley) (OC)
2. Wireless communication for sensors and control (Brambley) (OC)
3. Flexibility (suggested to strike out),
4. Interpretability (OC),
5. Life safety,
6. Operations (Agami)
7. Interoperability with third party applications
8. Life cycle models
9. Better access to information
10. Response to individual occupants (comfort)
11. Smart elevators for evaluation
12. Automated purchasing of energy (Brambley) (OC)
13. Autonomous buildings, self generating buildings (Michael-KM) (SS)
14. Demand management, Responds to real time pricing (Shipley) (OC)
15. Zero waste production (Brambley)
16. Flexible and configurable work space
17. Optimized operation (OC)
18. Building originated data distributed, building as a data sorce (Marty) (SS)
19. Self cleaning (replace cleaned with maintained, Arthur) buildings (gases (air), liquid, solid) (Brambley) (SS)

Categorizes proposed by Phil:

A. Security
B. Operations
C. Information management – gathering data throughout the buildings lifecycle
D. Environmental

M. Brambley suggested two categories:

1. Ultimate outcomes, what you want to provide
2. Improved operations

Phil: What are the long term research needs to address these issues? Is there a specific research idea or topic to addresses these issues?

Phil: Interoperability issues are being perused. We have an interest in, but has a toe whole in this area, TC 1.5, GPC 20 (XML for HVAC).

Phil: Need broad research needs for the next 5 years.

1. OC – optimal control
2. SS - Self-sufficiency

Rich H: What is the difference between a high performance bldg and a smart bldg? Brambley/Phil: high performance can refer to static measures, smart refers to taking care of itself, automated reconfiguration.

Phil handed out our chart on research topic timeline. Comments include:

Integrate automated commissioning and diagnostics (Phil, Brambley)

[Self configuring & integrated control] change to [systems and control integration] (Brambley)

John H. and J. Braun pointed out that we have a document on the elements of a smart building that can help in the exercise.

Change automated diagnostics to continuous commissioning or related term?

Arthur: Do we have to worry about other TC? Phil: TC 4.6 (optimal controls), TC 1.4 (controls). Les: Lets take time to discuss this in the main TC meeting.

Brambley: What is the expected outcome of this exercise? Phil was hoping to be more specific than we got here. For example, define specific areas under FDD. This exercise is too general to be useful now. To general leads to the conclusion that we are having difficulty focusing.

Brambley: Suggests everyone making research suggestions under broad categories.

Les: Concern, 2 RTARs/year, need to work more with other TCs, days are over of cranking out WS that interest us, need synergies.

Brambley: Are we looking for a couple of research ideas to partner with other TCs. Are we looking for a broader frame work?

Phil: Interaction with other TCs: Controls area (TC 1.4), TC.4.6, and a big focus on FDD as our primary area. What are our long term aims in FDD?

Brambley: Divide into subgroups, find a champion in different areas(e.g. 1.4/4.11, 4.6/4.11, 9.9-diagnostics/4.11).

Rich H: Goal is find a path to getting work done more than getting ideas organized. How do we insure our idea is the one that gets funded. Marty agrees. How to sell individual projects in the context of broader goals?

Notes taken by: Todd Rossi

Appendix G.

TC 4.11 Smart Building Systems

Research Plan and Activities

July 2000

Research Objectives: The long-term goal of TC 4.11 is to conduct research on topics that will lead to the development and application of "smart" building systems. "Smart" buildings of the future will take advantage of automation, communications, and data analysis technologies in order to operate in the most cost-effective manner. A smart building would most likely have fully integrated control of building services such as HVAC, fire, security, and transportation. Integrated systems would reduce initial costs and could be "supervised" so as to meet the primary objectives of comfort, safety, and performance at minimum operating cost. In addition, the integration of the hardware and software for operation and monitoring of equipment would lead to reductions in support staff needs and improved equipment reliability. Further cost reductions and reliability improvements would be possible through the integration of automated techniques for detection and diagnosis of equipment faults. Ultimately, "smart" building systems could facilitate the use of "remote" support staff that operates, monitors, and maintains a number of different buildings from a centralized location. At this higher level, a smart building might communicate and inter-operate with other smart buildings for the purpose of load aggregation and centralized control and with outside service providers, such as utilities, energy providers, aggregators, and newly developing companies providing fault detection, automated commissioning, optimization, and other innovative services. In addition to the savings in operating costs associated with "smart" buildings, other benefits include energy conservation and enhanced occupant safety and comfort.

Three subcommittees form the backbone of the TC’s activities: Technology Development, Communications and Integration, and Testing and Evaluation. The Technology Development Subcommittee is concerned with research issues associated with the development of emerging smart building technologies such as automated commissioning, performance monitoring, fault detection and diagnosis, optimal maintenance scheduling, and optimal control. The primary outcome of research endorsed by this subcommittee is expected to be data and models that enable development of the technologies and comprehensive methods that are the basis of the technologies. The Communications and Integration Subcommittee is concerned with research issues associated with enabling the seamless interaction of smart building components and services. An important aspect of this work is to identify the information that is necessary to support smart building technologies, and to identify the requirements of communication protocols to support the exchange of this information between different building services, between buildings and utilities, between multiple buildings, with outside service providers, etc. The Testing and Evaluation Subcommittee is concerned with research issues associated with assessing the benefits (market potential) and performance of smart building technologies. Research endorsed by this subcommittee is expected to result in data, metrics, methods, and tools/standards/guidelines for quantifying smart building system benefits and performance in a standardized manner, as well as findings from the actual application of these metrics, methods and tools.

Current TC 4.11 research includes projects in many of these areas. The evaluation of communication protocol requirements between utilities and energy management systems was addressed in the recently completed research project 1011-RP. Fault detection and diagnostics (FDD) is being considered for a number of different HVAC applications. Demonstration of the performance and benefits of current FDD approaches for air handling systems was performed as part of the recently completed research project 1020-RP. Tools for enabling the assessment of FDD methods for chillers are being developed in 1043-RP, while the development of on-line training techniques for model-based FDD methods is being carried out in 1139-RP for vapor compression equipment.

Revised 6/29/01, after Cincinnati meeting

TC 4.11, Smart Building Systems

Research Plan and Activities

June 2001

Current Research Projects

1043-RP - Fault Detection & Diagnostic Requirements & Evaluation Tools for Chillers

1139-RP - Development and Comparison of On-line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

Preliminary 2001-2002 Research Plan

Priority	Project	Contributors	Status
1.	Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II	John House Srinivas Katipamula Arthur Dexter Osman Ahmed	Approved in Minneapolis 10-0-0 (CNV). Need to submit to RAC AFTER Phase I (1043-RP) is completed. RTAR approved 9/00. No-cost extension to 3/02; however, project expected to be completed by 9/01. Submit WS to Seaton before 9/15/01.

2.	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Todd Rossi Mark Breuker Jim Braun	Draft WS exists. RTAR rejected 9/00. Revised RTAR to be submitted by 8/01/01 as priority 1 RTAR for 2001. Todd Rossi and Dave Shipley will assess number of units necessary for statistical significance and revise WS scope and budget accordingly.
3.	Method of Testing FDD Tools for AHU's (Was "Benchmarking of FDD Tools for AHUs")	John House Les Norford Mike Brambley Phil Haves Chariti Young Andrew Price	RTAR to be submitted by 8/01/01 as TC 4.11 priority 2 RTAR for 2001. WS to be prepared for Atlantic City subject to approval of RTAR.
4.	Smart Sensor Systems for Reducing Bias Errors in the Measurement of Air Temperatures and Flows in Air-handling Units (Was "Development of Fault Detection and Diagnostics for Sensor Failures")	Arthur Dexter Phil Haves	Two page Issues Paper handed out by Phil Haves in Minneapolis. Revised two page write-up distributed by Arthur Dexter in Atlanta. Arthur will revise to focus on a particular application. Arthur has been asked to expand this to a WS for Atlantic City.
5.	Design of Self-Configuration Concepts for an HVAC Control System	Michael Kintner-Meyer	RTAR exists.
6.	Prototyping and Field Testing of Utility – Consumer Information Services	Michael Kintner-Meyer Marty Burns Chuck McParland	SSPC 135 has reviewed the WS and set up a utility/building interface working group. This group will work with TC 4.11 to identify research needs in this area.
7.	Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Mike Brambley Todd Rossi	Mike Brambley scaled back scope and distributed a revised WS in Atlanta. TES thought "looked good". Need to submit revised RTAR.

Title: Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied Research

TC/TG Priority: 1

Estimated Cost and Duration: $120,000 and 18-months

Other Interested TC/TGs:

Possible Co-funding Organizations:

Handbook Chapters Affected by Project Results:

State of the Art (Background):

Recent research and development efforts have made significant progress toward enabling FDD for vapor-compression equipment; however, given their impact on comfort and energy use, there have been relatively few studies aimed at chillers. To address the need for a comprehensive study of automated diagnostics for chillers, a three-phase research project was initiated in 1998. Phase I was aimed at identifying the important faults for chillers and the sensors needed to detect and diagnose the faults, and developing some of the tools (laboratory chiller data and a simulation model capable of producing representative chiller data) for testing various chiller FDD methods. A more detailed description of the scope and findings of Phase I is provided in the ensuing paragraph. Phase II will focus on adapting and implementing existing FDD methods for application to a chiller, developing additional tools for assessing the performance of FDD methods, and using the Phase I and II tools to identify the most appropriate FDD method(s) for laboratory and field testing. The third phase of the study will be aimed at performing real-time laboratory and field testing of the FDD method(s) recommended in Phase II in order to ascertain the performance of the tools under non-ideal conditions. It is envisioned that the outcome of Phase III will be a chiller FDD algorithm for incorporation within commercial products.

Phase I (1043-RP) identified important chiller faults and the sensors necessary for detecting and diagnosing these faults. Literature reviews performed as part of Phase I summarized studies of FDD methods applied to HVAC equipment and systems, and chiller modeling. The chiller modeling literature review established that dynamic models capable of capturing the main dynamic characteristics of chillers do not exist. A dynamic model is needed for simulating fault-free and faulty chiller performance under real (steady-state and dynamic) operating conditions so that in Phase II, the output of the model can be used to evaluate thoroughly the effectiveness and robustness of various methods that might be utilized for chiller FDD. The dynamic chiller model was another deliverable of the Phase I project. In addition, laboratory data for normal operation and a number of fault conditions (at various levels of severity) were collected at various load conditions (27 different operating states were considered) for a 90-ton centrifugal chiller. The data collected included both transient and steady state conditions for the following faults: reduced water flow in the condenser, reduced water flow in evaporator, refrigerant leakage, refrigerant overcharge, presence of excess oil, condenser fouling, presence of non-condensables in the refrigerant, and faulty expansion valve.

Advancement to the State of the Art (Justification):

A significant portion of the energy and maintenance costs for operating commercial HVAC systems is associated with chillers. Although current control systems typically monitor many variables, this information is not used for diagnosing faults. At best, these systems incorporate automatic shutdown procedures that guard against catastrophic failures. Although there is a large body of literature on FDD techniques for applications in critical processes and the body of literature for HVAC systems is growing, very little has been published for chillers. Due to the large scope of the problem, studies related to FDD of chillers have typically focused on the development and evaluation of a particular FDD method and have not attempted to perform a rigorous comparison of a variety of FDD techniques. Research is needed to evaluate existing on-line methods for detecting and diagnosing common faults in centrifugal chillers. Furthermore, a side-by-side comparison of FDD methods by a single researcher using a common set of tools will help establish the most promising on-line FDD method(s) for chillers. Identification of reliable FDD methods for chillers will not only improve the operational performance but also reduce both energy and maintenance costs of chillers. This study will provide a major contribution to the field of FDD for chillers by:

- developing methods for evaluating FDD methods for chillers,
- identifying, adapting and implementing in software FDD methods appropriate for chillers, and
- evaluating the FDD methods using tools from Phase I (data and simulation model) and Phase II (FDD assessment tool).

The result of this study (Phase II) will be the identification of an FDD method (or methods) that is recommended for laboratory and field testing in Phase III. The overall impact of the three-phase study will be to advance the FDD technology closer to widespread commercialization.

Justification and Value to ASHRAE:

The main benefit to the ASHRAE membership will be a major step in the development of methods that, when implemented in new and existing chillers, will detect and diagnose operating faults before they become problems, thereby reducing maintenance costs, energy costs and occupant discomfort associated with the operation of cooling systems.

Objective:

The objectives of this study are:

1. To develop procedures for evaluating and comparing FDD methods for centrifugal chillers;
2. To assess the performance of FDD methods for chillers using data generated from a dynamic chiller model and data collected from laboratory tests;
3. To recommend cost effective chiller FDD method(s) for real-time laboratory and field testing in Phase III.

Title: Field Performance Assessment of Packaged Equipment to Quantify the Benefits of Proper Service and Assessing the Long

Term Need for Monitoring, FDD, and Continuous Commissioning Technology

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied

TC/TG Priority: 1 (2001-2002)

Estimated Cost and Duration: $150,000 ($125,000 ASHRAE + $25,000 DOE) and 24 months.

Other Interested TC/TGs: TC 9.9 (priority #2)

Expected Co-funding: $25,000 co-funding for this project promised by the U.S. Dept. of Energy.

Handbook Chapters Affected by Project Results: The results will be incorporated in few handbook chapter on Smart Building Systems.

State of the Art (Background):

Packaged HVAC equipment is the most common source of heating, air conditioning, and ventilation in small- and medium-size commercial buildings, including popular suburban retail shopping malls, supermarkets, and restaurants. Compared to large built up systems, packaged equipment are generally smaller and more numerous. Therefore, technicians spend less time servicing individual packaged units and the resultant field performance of this equipment may be much worse than that of their counterpart in built up systems.

Studies performed to date to assess the field performance of packaged equipment have been limited in scope and somewhat inconclusive. In 1992 and 1993, an HVAC/Refrigeration tune-up pilot program was implemented in Wisconsin to evaluate the effectiveness of HVAC and refrigeration tune-ups in saving energy and reducing peak demand in nine commercial buildings. The results varied widely, but energy savings of up to 15% were achieved in most buildings. Four major limitations to the study were cited including; (1) the number of sample points was small; (2) other factors affected building energy consumption; (3) HVAC performance enhancements improved comfort but did not always save energy; and (4) it was difficult to quantify the effect of particular maintenance activities without better controlled conditions or more sample points. A two-year study by the Electric Research Power Institute that was concluded in 1997 investigated the energy and demand impacts of maintenance on rooftop packaged heating and cooling equipment. Six long-term and 24 short-term sites were monitored. The short-term sites established the immediate impact of maintenance on savings and the long-term sites determined its persistence. The most prevalent problem was low refrigerant charge. No significant change in unit performance due to low charge, filter maintenance, or coil cleaning was observed. The study concluded that the cost of annual maintenance programs are unlikely to be offset by utility cost savings alone.

Other than these studies it is generally unknown how packaged equipment performs in the field. Laboratory studies of rooftop units show that performance is sensitive to typical faults observed in the field, yet these studies provide mixed results. An open and unbiased ASHRAE sponsored research project provides opportunity for our engineering community to participate in a study to observe these effects in the field.

Advancement to the State of the Art (Justification):

This project takes additional steps toward quantifying the benefits of proper service in packaged equipment by assessing current performance of a statistically significant number of units in the field and documenting how the performance improves when a subset of these units are properly serviced. This approach will establish a more rigorous baseline than previous studies for the maximum possible benefits of proper servicing.

Packaged equipment performance has a direct impact on occupant comfort, indoor air quality and facility energy use in a large fraction of commercial buildings in the US. A recent DOE report indicates that rooftop and unitary A/C equipment consumes 1.03 out of a total of 1.66 quads (62%) of total energy consumed for cooling the current building stock of commercial buildings in the US. This research project will assess the level of improvement in energy efficiency that can be expected from proper servicing of packaged equipment, thereby establishing the need for diagnostic technology that can facilitate improved servicing of this type of equipment.

Justification and Value to ASHRAE:

Industry (i.e., building owners and facility managers) will benefit from this research by utilizing the results of the project to prioritize their maintenance and diagnostic efforts. The results will also help guide future efforts at ASHRAE, government and industry to develop technology and document its costs and benefits to help achieve widespread acceptance in the marketplace. Furthermore, the development of packaged equipment performance indices and experience with measuring, documenting, and reporting them will help researchers and product developers establish a unified approach to quantifying performance.

Objective:

The objectives of this research project are to study and document:

1. The actual field performances of 375 packaged HVAC units and compare them to industry norms or manufacturer's specifications for new equipment.

2. The implementation of diagnostic and proper service procedures and the resulting performance enhancement for at least 75 of the 375 units.
3. The need for monitoring, FDD, and continuous commissioning technology to address the long-term service needs of packaged equipment in the field.

To preserve generality and anonymity and to prevent competition between unit manufacturers, units are to be classified generically into categories including age, nominal capacity, refrigerant, type of expansion device, compressor technology, design EER, and electrical specifications. No make or model names or any other similar characteristics will be used to identify the units used in this study.

Bidders will be expected to collaborate with maintenance organizations such that this project will fund only the incremental costs of collecting and analyzing the data, not the cost of servicing.

Title: Method of Testing Fault Detection and Diagnostic Tools for Air-handling Units

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied Research

TC/TG Priority: 2 (2001-2002)

Estimated Cost and Duration: $75,000 and 15 months

Other Interested TC/TGs:

Possible Co-funding Organizations:

Handbook Chapters Affected by Project Results: The results will be incorporated in few handbook chapter on Smart Building Systems.

State of the Art (Background):

This RTAR describes a follow-on study to ASHRAE 1020-RP, "Demonstration of Fault Detection and Diagnostic Methods in a Real Building" (Norford et al. 2000). The objective of 1020-RP was to demonstrate FDD methods in a real building, to assess the strengths and weaknesses of the methods investigated, and to provide guidance for future research in this area that will accelerate the development of FDD technology. The comparison included data for seven different faults collected during multiple seasons of the year. Both abrupt and degradation faults were considered. The data was collected at the Iowa Energy Center Energy Resource Station, a real building that serves as a test facility for energy-efficient technologies. The test procedure consisted of the following three steps:

1. preliminary commissioning tests,
2. one-week of control tests in which faults were implemented and the researchers were told what faults were implemented (including severity), at what time they were implemented, and for how long they were implemented, and
3. one-week blind tests in which the researchers knew only that the faults considered during the control tests would be implemented at some time during that week.

Step 1 was performed once, while steps 2 and 3 were performed once during summer conditions, again during winter conditions, and a final time during spring conditions. Both FDD methods proved capable of consistently detecting the faults, with a small number of exceptions. Fault diagnosis procedures were improved over the course of the tests and at the conclusion were also generally effective. However, diagnosis was made considerably easier than in what are likely to be typical conditions, due to the limited number of known faults, the known magnitude of the faults, and the excellent maintenance of building equipment and sensors.

The test procedure was then altered to evaluate the performance of the methods without the benefit of the control test data. The new test procedure was carried out on a different AHU and the researchers were not told what faults were implemented. The performance of the methods suffered with the removal of step 2. In particular, the ability to diagnose the implemented faults was poor.

Advancement to the State of the Art (Justification):

Prototype FDD tools for AHUs have been in existence for several years. It is estimated that there are currently at least 8 to 10 AHU FDD tools at various stages of development. At least one of these tools is being marketed to building owners and operators, although none are currently implemented directly in energy management and control systems. Controls manufacturers are moving cautiously toward implementing FDD capabilities in their controllers, tempering their desire to improve their products with the reality that the technology is still in its infancy. This conservative approach is understandable. ASHRAE 1020-RP illustrated how challenging it is to detect and diagnose faults in real buildings and, furthermore, how challenging it is to evaluate FDD tools. This work statement seeks to address this second challenge by developing a testing methodology for AHU FDD tools as well as the supporting data and metrics necessary to carry out the tests.

Justification and Value to ASHRAE:

Establishing accepted testing methodologies represents an important step in the development of new products. ASHRAE currently has a guideline under development establishing a method of testing building HVAC control systems. The methodology and the supporting data and metrics developed in this project will enable developers of AHU FDD tools to assess their performance in a "standardized" manner. In doing so, commercialization of FDD technology will be expedited, thereby benefiting building owners, operators, and occupants by helping ensure buildings are comfortable and utilize energy efficiently. This project could represent an important first step in the establishment of an ASHRAE guideline for testing FDD tools.

Objective:

The primary objective of this study is to develop a comprehensive testing methodology for AHU FDD tools that can be used to establish the capability of a given FDD tool to detect and diagnose faults in real buildings. A secondary objective of the study is to produce data sets and evaluation metrics to be used in conjunction with the test method.

Title: Smart sensor systems for reducing bias errors in the measurement of air temperatures and flows in air-handling units

TC/TG: TC4.11 Smart Building Systems (Arthur Dexter)

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied

TC/TG Priority: 4

Estimated Cost and Duration: $100,000 and 18 months

Other Interested TGs/TCs: TC 1.4; TC 4.6

Possible Co-funding Organizations:

Handbook Chapters Affected by Project Results:

State of the Art (Background):

The presence of significant measurement errors is one of the main barriers to the automatic detection of many important faults in air-conditioning systems. For example, the air temperature difference across a coil may be more sensitive to the offset errors associated with the measurement of the on-coil air temperature than it is to fouling of the coil.

The accurate measurement of the temperature and velocity of the air flowing down a large duct is extremely difficult when there are significant variations in the temperature and velocity over the cross-section or radiant energy gains from surrounding surfaces. Current sensors are either very inaccurate or very expensive. Even currently available commercial averaging sensors for measuring air temperature and air flow rates can produce large errors in certain locations (for example, immediately downstream of a mixing-box or heat-exchanger).

Advance to the State of the Art (Justification):

There are two basic causes of the errors (i) faults associated with incorrect installation or calibration of the sensor (ii) the use of a single sensor to measure average value of a spatially distributed variable. Sensor faults can be eliminated during commissioning but the errors arising from spatial variations are more difficult to eliminate, particularly if the spatial distribution changes with operating conditions. Here the problem is not the accuracy or precision of the sensor itself but estimation bias.

The measurement accuracy can be improved without increasing the cost of the sensors by using techniques such as data fusion, based on Kalman filters or fuzzy logic, or inferential measurement schemes.

Justification and Value to ASHRAE:

Objectives:

The objectives of this research are to:

1. determine the magnitudes and causes of the bias errors associated with current sensors that are used to measure duct air temperature and flow rate
2. investigate ways of automatically detecting and identifying the magnitude of these errors
3. develop techniques for automatically compensating for these errors

4. demonstrate the practical benefits of such techniques in fault detection and diagnosis

The work would involve:

1. examining the literature and performing experiments to obtain a better understanding of the relationship between the output of the sensor and the quantity to be estimated, under different operating conditions.
2. investigating ways of generating an estimate of the uncertainty associated with the output of the sensor
3. identifying other information (for example, auxiliary or additional measurements and control signals) that could be used to reduce the uncertainties. For example, another estimate of the air-flow rate is related to the fan control signal; the temperature distribution downstream of the mixing-box is related to the control signal to the dampers; the radiant energy gain experienced by a sensor located close to a coil is related to the coil's valve control signal.
4. quantifying the uncertainties associated with the these information.
5. developing a smart sensor system that is capable of more accurate measurement.
6. assessing the benefits of using such sensors with fault detection and diagnosis schemes by experiments in a real building or laboratory test rig.

References:

Carling, P. and Isakson, P. 1999. Temperature measurement accuracy in an air-handling unit mixing box. The 3rd International Symposium on HVAC, ISHVAC '99. Shenzhen, China.

Kelso, R. M., Marshall, P. H. and Baker, A. J. 2000. A CFD study of airflow in a mixing-box, Proc. CIBSE/ASHRAE conference, Dublin, Ireland.

Robinson, K. D. 1999. Mixing effectiveness of AHU combination mixing-box /filter-box with and without filters, Trans. ASHRAE.

Wang, S. W., and Wang, J. B. 1999. Law-Based Sensor Fault Diagnosis and Validation for Building Air-conditioning Systems, International Journal of HVAC&R Research, 5(4), pp.353-378.

Title: Design of a Self-Configuration Concepts for HVAC Control System

TC/TG: TC 4.11 Smart Building Systems

Research Category: Design, Operation, and Maintenance Tools

Research Classification: Basic and Applied Research

TC/TG Priority: 5

Estimated Cost and Duration: $100,000 and 24 months

Other Interested TC/TGs: TG 1.4, SSPC 135

Possible Co-funding Organizations: New York Energy Research and Development Authority

Handbook Chapters Affected by Project Results:

State of the Art (Background):

The set-up and configuration of sophisticated HVAC control system in large buildings is difficult, time-intensive and error-prone. Thousands of sensors, controllers, and actuators control points need to be uniquely addressed and a binding list needs to be established specifying the connectivity between control devices. This task is labor intensive. It requires meticulous documentation of device addresses and data flow for all control points in the network in order to verify the proper operation of the control system for the building commissioning and for potential system modification later on. The large number of control points and cryptic names of the device addresses often lead to errors by binding controller inputs to wrong sensors. The trouble shooting of these errors are expensive and often remain unnoticed wasting valuable resources.

Faced with a similar challenge, the computer network industry has developed 'plug and play' concepts that support flexible and user-friendly set-up and configuration of personal computers, printers, and other devices to local area networks and the Internet. Technologies such as Sun Microsystems' Jini™ and Microsoft's Universal Plug and Play, have emerged over the last several years that provide concepts of self-configuration and automatic set-up procedures. These technologies enable end-users to install and connect new hardware and software to the computer networks and use distributed printing and other network services. These technologies reduce the time for network configuration and set-up and assure robust network operation by recognizing changes to the network as new devices are being installed and removed.

Over the last decade, the building automation industry with the leadership of ASHRAE has been successful in developing BACnet as communication standard so that information can be shared between devices from different vendors' products. The next logical step for the advancement of the HVAC controls industry is the development of self-configuring and plug and play technologies [ASHRAE 135-1995].

Today's state-of-art in building control systems falls far short of plug and play expectations. Plug and play capabilities cannot be achieved by standardizing the hardware specification and the communication protocol alone. In addition, the control devices need more intelligence to be able to support self-configuration that supports the interaction between the devices.

Advancement to the State of the Art (Justification):

The development of self-configuring strategies for HVAC control systems is a natural and logical extension of the ASHRAE's efforts and leadership in promoting communication standards and the interoperability of intelligent HVAC control devices. It will advance the technology to the next level by greatly reducing the time for controls engineer to set-up the control system with multi-vendor products. It will provide an even greater benefit to the building operator and owner by assuring the consistent system configuration that can be easily re- or retro-commissioned to maintain high building system performance as the building undergoes many changes during is life-cycle. It would reduce the set-up cost for emerging and new fault detection and diagnostics products that require a data interface to the HVAC control system.

The industry is not likely to lead this effort because significant coordination efforts for the specification of self-configuration and plug and play standards among all stakeholders. It, therefore, necessary that a standards organization will need to step forward to demonstrate leadership that will advance the industry. ASHRAE is well positioned to fulfill this role through its leadership and commitment to develop the BACnet standard over the last decade.

Justification and Value to ASHRAE:

This research will initiate a new technology development direction that has the potential of significant impacts on the performance of and the energy consumed in buildings. If and when self-configurating HVAC control systems are matured as a commercially viable technology, they will significantly reduce system set-up cost while assure a high quality of service. They will enable user-friendly installation of fault detection and diagnostics tools and software and streamline and improve the re-commissioning process.

Objective:

The objectives of the work are:

1. To develop a set of requirements for a self-configuration concept that are specific to the HVAC control system.
2. To design a self-configuration concept for HVAC control system and provide examples for the implementation of the self-configuration concept for a set of commonly used HVAC control subsystems (e.g., unitary controller, AHU controller, chiller controller).
3. To advice ASHRAE on what role it should or could take in advancing the concept to a technology.

Reference:

ANSI/ASHRAE Standard 135-1995. BACnet - A Data Communication Protocol For Building Automation and Control Networks. ASHRAE, Atlanta, GA. 1995.

Title: Prototyping and Testing of Utility/Customer Information Services

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Advanced Concepts

TC/TG Priority: 6

Estimated Cost and Duration:

Other Interested TC/TGs: TC 1.4, TC 1.5

Possible Co-funding Organizations:

Handbook Chapters Affected by Project Results:

State of the Art (Background):

Utilities and telecom companies have been experimenting with energy and non-energy information services for several years. Most of the experimentation has been performed in small-scale pilot programs with a relatively small number of participants. The majority of the technology implementations are centered around providing services such as automatic meter reading, outage detection, and real-time-pricing (RTP) transmission. Only recently, spurred by the restructuring efforts in the electric power industry and the Telecommunication Act of 1996, has the industry has made bolder steps in marketing and implementation of information services.

On-site power generation from emergency generators has only recently been offered by technology companies and generator manufacturers. Web-based applications have emerged that provide gateway capabilities to interface commonly used EMCS. These systems can be bundled with other asset management services to provide full solutions to property management companies and ESCOs for load management, energy efficiency monitoring, alarm response, and diagnostics, as well as providing facility management functions such as asset inventory, facility maintenance scheduling and automated processing of work orders and procurement.

Direct load management applications are predominant in residential homes, where appliances such as air conditioners, pool pumps, and water heaters were cycled during peak times to reduce load. Most of the residential information services offered are Internet and cable TV services. However, given that a communication infrastructure is being developed by means of these applications, the same communication device transmitting entertainment information can be used to transmit energy information service in future applications.

By and large, utility trials have focussed on implementing some targeted applications. Most of these were not concerned with the development of underlying communication infrastructures that would provide interoperability across network and communication technologies. Now the industry needs to complete the development of standards necessary to enable these services to a broad customer base including commercial, industrial and residential customers. Significant steps toward that end have already been done. The Electric Power Institute (EPRI) with its Utility Communication Architecture standardization efforts and, recently, ASHRAE with its support of research project 1011-RP are providing a systematic approach toward defining communication standards targeted at utility-customer communications.

Advancement to the State of the Art (Justification):

As a natural extension of ASHRAE research project 1011-RP, "Utility/Energy Management and Control System (EMCS) Communication Protocol Requirements", a two phase project for prototyping and field testing a set of selected information services defined in research project I011-RP is proposed. Phase I will focus on the prototyping and testing of information services under lab conditions in which the communicating parties are simulated. In Phase II, field trials will be proposed to implement and test the prototyped information services at 3-5 customer sites under real-world conditions. This RTAR describes Phase I only. Phase II will be defined in a later, separate RTAR.

The primary objectives of research project 1011-RP were: 1) to identify potential new information services that utilities or electricity suppliers are likely to offer to their customers, 2) to determine the communication and data requirements to establish these services, and 3) to develop data object models that support interoperability for the implementation of the services. This project will build on this previous work. It will implement and test selected information services for commercial/industrial and residential applications in BACnet and CEBus environments. To expedite the prototyping and testing phase, the development is proposed to be performed in a simulated environment in which the communication between a utility/service provider and its customers is simulated in several networked computers under laboratory conditions. This work is specifically designed to verify the completeness, usability, of the set of data object models developed in 1011 - RP through a real implementation. By using the BACnet protocol for in-building communication it will build on and support the ASHRAE's standards work.

Justification and Value to ASHRAE:

Objective:

The implementation of a prototype of selected energy/information services will target the

following objectives:

1. To verify the completeness of the data object and device models for selected energy and information services proposed under ASHRAE 1011-RP. The implementation will check the completeness and provide a basis for proposing enhancements/ modification to the object models.

2) To test the mapping of the data object models to BACnet and CEBus protocols, since the seamless bidirectional transport of information is imperative for robust communication.

3. To provide experience with real implementation and provide the credibility and the refinement necessary to establish communication standards for energy/information services.
4. To assist the development of communication software necessary for the preparation of energy/information services to be studied in field trials during Phase II.

Title: Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection, and Diagnostic (FDD) Systems

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied

TC/TG Priority: 7

Estimated Cost and Duration:

Other Interested TC/TGs: TC 4.6

Possible Co-funding Organizations:

Handbook Chapters Affected by Project Results:

State of the Art (Background):

Large systems, including buildings, can be represented in a hierarchical structure where the entire system is divided into sub-systems, which are in turn divided into sub-sub-systems. Fault detection and diagnostic (FDD) methods or software modules can operate on one or more levels or at different levels throughout this hierarchical structure. Such systems promise to provide the greatest benefits for large systems (e.g., all the HVAC equipment in a 40 story building) that need the hierarchical structure to divide the system into manageable components, but the hierarchical structure could be applied to smaller buildings and may be of value in implementing the diagnostic processes themselves.

When FDD methods operate on hierarchically-related entities, they may produce results that contradict one another. Subsystems have interactions (consider, for example, the chilled water temperature that is produced by the chiller and used by cooling coils). This, along with uncertainty in measured conditions, creates the potential for overlapping and conflicting results when FDD methods are applied to different individual entities at different levels or subsystems in the hierarchy. For example, the chiller FDD might call for a warmer chilled water temperature while some of the cooling coils it serves call for a lower chilled water temperature. For a building operator to use advice from these distributed, independent FDD systems, some coordination of their results or resolution of conflicts is needed. Conflict resolution might be done manually by the FDD user (e.g., building operator), automatically at a supervisory level (e.g., on the operator workstation), or automatically at distributed points in the FDD system.

This work statement focuses on resolving conflicts between FDD solutions that are likely to utilize distributed computing (i.e., processing takes place at multiple locations distributed throughout the building and/or control system), but it also applies to FDD methods implemented as separate processes or software modules run on the same computer.

Advancement to the State of the Art (Justification):

Fault detection and diagnostic (FDD) techniques are emerging from research and are beginning to be tested in real buildings. Many of these techniques focus on specific HVAC subsystems or components of them; others operate at the whole-building level to identify performance anomalies and identify subsystems causing the anomalies. At the same time, control functions are becoming more distributed with much control processing (computing) taking place at the device or subsystem level, rather than at a central (building-level) location. This provides opportunities for the use of distributed FDD in conjunction with distributed control, yet creates the need to coordinate and resolve conflicts between diagnostic results produced by different FDD systems. This research project responds to that need by providing information that will be needed by the HVAC professions to successfully apply distributed FDD in buildings by developing and evaluating methods for resolving conflicts between FDD systems.

Justification and Value to ASHRAE:

Objective:

The objective of this research is to investigate how results from FDD methods applied separately to distributed and hierarchically-related HVAC subsystems and equipment can overlap and potentially conflict with one another. Then, based on this investigation, identify, develop and validate, test and evaluation methods for resolving these conflicts. The final results of this research will be a well-documented evaluation of methods for overcoming conflicts generated by FDD methods or software along with guidance regarding circumstances under which to use each adequately-performing method. The final document shall include detailed examples of method applications.

TC 4.11 Smart Building Systems Research: Past, Ongoing and Planned

Appendix H.

List of Subcommittee Attendees

Atlantic City: January 1, 2002

	Technology Development	Communications & Integration	Testing & Evaluation	Research
Voting Members				
Les Norford, Chair (V)	x	x	x	x
John House, Vice Chair, Research Subc (V)	x	x	x	x
Michael Kintner-Meyer, Communications and Integration Subc (V)	x	x	x	x
Todd Rossi, Fault Detection Diagnostics Subc, (V)	x	x	x	x
Natascha Castro, Secretary, Web Master (V)	x		x	x
Steve Blanc, (V)	x	x	x	x
Barry Bridges (V)	x			x
James W. Gartner (V)		x		
Rich Hackner, (V)	x	x	x	x
John Seem, (V)				
Mike Brambly, Testing and Evaluation Subc, CM	x	x	x	x
Phil Haves, (V)	x	x	x	x
Agami Reddy, CM	x	x	x	x
John Mitchell , CM	x		x	x
Carlos Haiad, (V)				
Srinivas Katipamula (V)				
Arthur Dexter, International member (V)	x		x	x
Non-Voting Members				
Michael Brandemuehl, CM				
Thomas Engbring, CM				
Brian Kammers, CM				
Ron Nelson, CM				
Barry Reardon, CM				
Dave Branson, CM				
James Braun, CM	x			
Hung Mahn Pham, CM				
Robert Old, CM				
George Kelly, CM				
Carol Lomonaco, , CM Program Subc				
Charles Culp, CM				

David Kahn, CM				
Osman Ahmed				
Peter Armstrong	x	x	x	x
Jim Butler	x	x		
Peter Gruber				
Keith Temple				
Peng Xu	x			
Don Aymann				
Jon Douglas	x	x	x	x
Tim Salsbury	x	x	x	x
Par Carling	x	x	x	x
Rodney Martin	x	x	x	x
Virgil Seribo		x		
Hofu Kiu	x			
Gene Strehlow			x	
Song Zhang		x		
David Shipley			x	
Kirstin Heinemeier			x	
Paul Reimer				
Glenn Remington				
Zach Obert				
Curtis Klaassen				
Marty Burns	x	x	x	x
Cliff Federspiel				
Richard Kelso				x
Pornsak Songkakul				
Jean Christophe Visier			x	x
Jonathan Wright	x			